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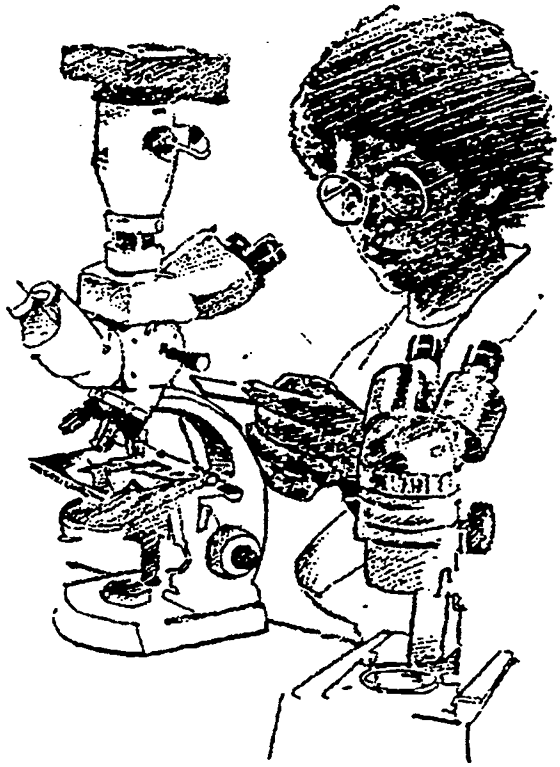
ABSTRACT

This module presents a real-world context in which mathematics skills are used as part of a daily routine. The context is the medical laboratory technology field, and the module aims to help students develop the ability to use mathematics computations while performing tasks similar to those performed by a medical technologist. Materials in the module, most of which are designed for the teacher to duplicate and distribute to students, include the following: (1) information on careers in the field of medical laboratory technology; (2) a task to be performed; (3) task skills, sample problems, related problems, and a teacher's answer key; (4) a glossary; and (5) related diagrams. (KC)

ED 360 531

MATHEMATICS FOR THE WORKPLACE



APPLICATIONS FROM MEDICAL LABORATORY TECHNOLOGY

A TEACHER'S GUIDE

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TABLE OF CONTENTS

INTRODUCTION

This module is designed as an additional resource for teaching fractions and decimals and their applications to "real-world" situations. The applications in this module are from the allied health field of medical laboratory technology.

Teachers who use this module should be aware of its applicability to several areas of mathematics. This module can be used as part of the regular instruction for such courses as General Math, Technical/Applied Math, or Algebra I.

An additional suggestion of how to use this module is to invite, when possible, a medical laboratory technician to speak to the class with which this module is to be used. This module can then be implemented as a follow-up activity over the next several days, giving students an opportunity to work problems associated with a medical laboratory technician's job responsibilities.

However, keep in mind these are only suggestions. Each teacher and/or district will have to decide where the module best fits into the overall structure of the curriculum.

RATIONALE FOR THE UNIT

Many times students have difficulty relating concepts and theories presented in the classroom to real-life situations. This problem may occur when information is presented in an isolated setting. Students, who are unable to see a connection between what is taught and the real-world applications, often become disinterested in the subject. This can result in a lack of motivation on the part of the student. Consequently, the student perceives no need to apply himself to his studies and, therefore, he does not take courses which challenge him as a learner.

This module is designed to provide a real-world context where fractions and decimals are used as part of a daily routine. Providing examples from real-life settings helps students better understand the need to study and to learn the mathematical concepts taught on a daily basis. Real-life applications can provide the needed relevance to motivate students, not only to apply themselves to their studies but also to take the highest level of mathematics they are capable of handling successfully.

HOW TO USE THIS MODULE

The table of contents in this packet gives a listing of the concepts encompassed within the module. This is a teacher' guide, not a packet of material to be duplicated and presented to students. Much of the material within the packet is for the teacher's use only. There are, however, several sections which meed to be duplicated and presented to the students in order to have them complete the tasks.

Pages 3-4 give the students an introduction to the allied health field of medical laboratory technology. Included in this introduction is such information as the technicians, duties, where technicians work, and how to prepare for the field in high school. **These pages can be duplicated and given to the students as introductory information.**

Page 5 gives an explanation of the task and the need for the task. **This page can also be duplicated and given to the students as information.**

Pages 6-8 explain the specific tasks being presented in the module. If the teacher so desires, she may duplicate these pages and give them to the students. However, please bear in mind this is only a suggestion. If the teacher feels students do not need this information and that it can be best presented through lecture, then the teacher need not duplicate these pages.

Pages 9-12 are sample problems involving a white blood cell count and a red blood cell count. Again, if the teacher so desires, these pages may be duplicated and given to the students.

Page 13 gives related word problems for further practice of the skills presented. **This page can also be duplicated and given to the students.**

Pages 14-18 are the answer keys to the Related Problems. The answer keys give the solutions to each part of the related problems. Also, questions 5 - 7 are "thought" questions which require more than computations. Some possible answers are listed for each questions.

The Related Diagrams, pages 20-23, can be used as either overhead transparencies or can be duplicated and given to students as information.

EXAMINING THE PROFESSION

Description of Career

"A medical laboratory technician performs general tests in all laboratory areas."[1] Working under direct supervision of a medical technologist, a medical laboratory technician searches for clues in specimen samples for the absence, presence, extent, and causes of diseases.[2]

"Medical laboratory technicians (MLTs) must be accurate, dedicated, and skilled."[3] MLTs receive training through 2-year colleges or hospital programs and must pass a national examination to become certified. They must also be self-motivated, to take initiative to do what must be done every day--to pitch in as an important member of the health care team.[4]

Technicians should like:

- activities dealing with things and objects;
- using set methods and procedures;
- activities of a scientific and technical mature.

A technician should be able to:

- perform a variety of duties that may often change;
- attain established standards of accuracy;
- understand mathematical concepts.

Job Related Duties

"The medical laboratory technician performs routine laboratory tests in:

- blood-banking
- hematology
- microbiology
- chemistry
- immunology
- urinalysis."[5]

Other duties may include:

- collecting specimens for chemical analysis;
- setting up and maintaining laboratory equipment;
- analyzing samples for chemical content or reaction.

Working Conditions

Most technicians work in hospitals. Others may work in private laboratories, doctors' offices, clinics, public health agencies, pharmaceutical firms, research institutions, university laboratories, or industrial plants.

Technicians generally work a 40-hour week. Evening, weekend, and holiday work may be required for those employed by hospitals. Occasionally technicians are hired specifically for on-call, part-time, evening, or weekend assignments.

High School Preparation

In order to be best prepared to enter a program of studies in medical laboratory technology a student should take courses in algebra, biology, and chemistry.

Students may receive additional information on MLT careers or other mid-level allied health careers from their high school counselor or from area technical colleges.

Students may also consider becoming a volunteer at the local hospital to gain exposure to the various allied health careers.

SPECIFIC JOB RELATED TASK

Introduction to the Task

One specific task a medical laboratory technician performs is determining the red or white cell count in a blood sample. Cell counts above or below the normal range may indicate the presence of some type of infection. When a patient visits the doctor, one way of determining if there is an infection is to perform a white blood count (WBC) or red blood count (RBC).

The normal white blood count is usually between 5,000 and 10,000 cells per cubic millimeter.

The normal red blood cell count is between 4,000,000 and 6,000,000 cells per cubic millimeter.

Need for the Task

High white blood cell counts may indicate:

- appendicitis
- pneumonia
- meningitis
- other diseases.
- leukemia
- tonsillitis
- chicken pox

Low white blood cell counts may indicate:

- measles
- typhoid fever
- other diseases.
- influenza
- infectious hepatitis

Low red blood cell counts may indicate:

- undetected internal bleeding;
- severe anemia;
- bone marrow malfunctions.

High red blood cell counts may:

- cause high blood pressure;
- indicate bone marrow malfunctions.

It is extremely important for a MLT to be accurate because a miscalculation might result in:

- a wrong type of medication being issued to the patient;
- a disease going undetected;
- additional and unnecessary suffering for the patient.

Dilution

In order to calculate the WBC or RBC, a MLT must proceed through several steps. Once the blood has been drawn and place in the pipette, it is then diluted. Dilution ratio indicates the relative amount of substances in a solution.

Dilution is the ratio of the number of parts being diluted in a solution to the total number of parts in the solution. In RBC dilution, the ratio is the number of milliliters (ml) pulled up in the RBC pipette to 10 ml.

Example:

> If 1 ml of blood was drawn and the pipette was filled with solution to the 10 ml mark, the dilution ratio would be 1/10.

In a WBC dilution, the ratio is the number of ml pulled up in the pipette to 100 ml.

Example:

> If 1 ml of blood was drawn and the pipette was filled with solution to the 100 ml mark, the dilution ratio would be 1/100.

Dilution Factor

Since whole blood is not used in the counting process, a dilution factor is needed. In order to determine the dilution factor, the technician must be able to determine the dilution ratio.

The dilution factor is the reciprocal of the dilution ratio.

Example:

> If the dilution ratio is 1/10, then the dilution factor is 10.

Since the dilution ratio gives the ratio of blood to the whole solution, you must take the reciprocal of the dilution ratio in order to correct for diluting the solution.

Depth Factor

The entire counting process revolves around the fact that the technician is trying to determine the number of red or white blood cells in one cubic millimeter of blood. This would mean a cube one millimeter in length on all sides. The blood sample is placed in a chamber one millimeter in length by one millimeter in width but very seldom is the chamber one millimeter in depth.

The most common depth of the chamber is 0.1 mm. In order to compensate for this depth of less than one millimeter, a depth factor must be calculated. The depth factor is the reciprocal of the depth of the chamber being used in the counting process.

Example:

If the depth of the chamber is .1 mm then the reciprocal of that depth is 1/.1 or 10. If the depth of the chamber is .2 mm then the reciprocal of that depth is 1/.2 or 5. Taking the reciprocal of the depth of the chamber is the same a converting the chamber to a depth of one millimeter.

If no information is given concerning the depth of the chamber, assume a standard counting chamber with a depth of .1 mm.

Area Counted

For a RBC, the area counted is the ratio of the number of squares counted to the total number of squares (25).

Example:

If during the RBC process only 10 of the 25 squares were counted the area counted would be 10/25 or .4 square mm.

For a WBC, the area counted would be the actual number of 1-millimeter squares counted.

Area Factor

The area factor, which relates to the total number of squares counted on the hemocytometer, is the reciprocal of the area counted.

Example:

If 2 white cell squares were counted the area factor would be 1/2 or .5 square mm. If 10 red cell squares were counted the area factor would be 1/.4 or 2.5 square mm.

Volume Factor

The volume factor for the RBC or WBC is the area factor times the depth factor. This volume factor is equivalent to having a cubic millimeter of blood in the sample.

Total Cell Count

In order to determine the RBC or WBC, the technician must multiply the number of cells counted by the depth factor. This product must then be multiplied by the dilution factor. This second product must then be divided by the area counted. This gives the number of cells per cubic millimeter of blood in the body. It is this final number that the technician reports to the doctor in order for the doctor to make a diagnosis.

TOTAL CELL COUNT:

$$\frac{\text{NUMBER OF CELLS COUNTED} \times \text{DEPTH FACTOR} \times \text{DILUTION FACTOR}}{\text{AREA COUNTED}}$$

SAMPLE PROBLEM A: CALCULATING A WHITE BLOOD CELL COUNT

In a test to determine the number of white blood cells in a sample of blood, blood was drawn to the 0.5 ml level in a WBC pipette. 4 white squares were counted on the hemocytometer and 104 cells were found in the count. The depth of the hemocytometer chamber is 0.1 mm.

FIND: (a) dilution, (b) dilution factor, (c) depth factor, (d) area counted, (e) area factor, (f) volume factor, and (g) the number of cells/cubic mm.

STEP 1: Determining the Dilution Ratio

$$\frac{\text{The number of ml pulled up in the WBC or RBC pipette}}{\text{(10 for WBC pipette or 100 for RBC pipette)}}$$

The amount of blood pulled into the pipette is .5 ml. Therefore the dilution is:

$$\frac{0.5}{10} \quad \text{or} \quad \frac{1}{20}$$

STEP 2: Determining the Dilution Factor

The dilution factor is the reciprocal of the dilution ratio. The dilution ratio is:

$$\frac{1}{20}$$

The reciprocal is:

$$\frac{1}{\frac{1}{20}}$$

or 20.

STEP 3: Calculating the Depth Factor

The depth factor is the reciprocal of the depth of the chamber. The depth of the chamber is .1 ml. The reciprocal of .1 is:

$$\frac{1}{.1}$$

which simplifies to 10.

STEP 4: Determining the Area Counted

The blood was drawn in a WBC pipette, therefore, the area counted is 4 square millimeters.

STEP 5: Calculating the Area Factor

The area factor in a WBC is the reciprocal of the area counted. The area counted was 4 square millimeter, therefore the area factor for this sample is:

$$\frac{1}{4}$$

STEP 6: Calculating the Volume Factor

The volume factor is the area factor times the depth factor.

Area factor $= \frac{1}{4}$ Depth Factor $= 10$

$$\frac{1}{4} \times 10 = \frac{10}{4} = 2.5 \text{ cubic milliliters}$$

STEP 7: Calculating the Final Cell Count

The cells per cubic millimeter is the number WBC counted times the dilution factor times the depth factor divided by the area counted.

WBC counted = 104
depth factor = 10

dilution factor = 20
area counted = 4

$$\frac{104 \times 20 \times 10}{4} = 5{,}200$$

Therefore the WBC count is 5,200 cells/cubic millimeter.

SAMPLE PROBLEM B: CALCULATING A RED BLOOD CELL COUNT

In a RBC pipette the blood is drawn to the 0.5 ml level. Five red squares are counted. A counting chamber depth of 0.1 mm was used. 500 cells were counted.

FIND: (a) dilution, (b) dilution factor, (c) depth factor, (d) area counted, (e) area factor, (f) volume factor, and (g) cells counted/cubic mm.

(**NOTE:** The major difference between determining the red blood cell count and the white blood cell count is the denominator used in the dilution rate. The calculation steps are basically the same in both processes.)

STEP 1: Determining the Dilution Ratio

$$\frac{\text{The number of ml pulled up in pipette}}{\text{100 for RBC pipette}}$$

Since .5 ml of blood was drawn into the pipette, the dilution ratio is:

$$\frac{.5}{100} \quad \text{or} \quad \frac{1}{200}$$

STEP 2: Determining the Dilution Factor

The dilution factor is the reciprocal of the dilution ratio. The dilution ratio is:

$$\frac{1}{200}$$

The reciprocal of the dilution ratio is:

$$\frac{1}{\frac{1}{200}}$$

or 200.

STEP 3: Calculating the Depth Factor

The depth factor is the reciprocal of the chamber depth. The depth of the chamber is .1 ml.

The reciprocal of .1 is:

$$\frac{1}{.1}$$

or 10.

STEP 4: Determining the Area Counted

Since we are making a RBC count, the area counted is the number of squares counted divided by the number of squares that could have been counted.

The number of squares counted = 5.
The number of squares that could have been counted = 25.

The area counted is:

$$\frac{5}{25} \text{ or } \frac{1}{5}$$

STEP 5: Calculating the Area Factor

The area factor is is the reciprocal of the area counted.

Area counted was

$$\frac{1}{5}$$

The reciprocal is

$$\frac{1}{\frac{1}{5}}$$

or 5.

STEP 6: Calculating the Volume Factor

The volume factor is the area factor times the depth factor.

Area factor = 5 Depth factor = 5

5 x 5 = 25 cubic milliliters

STEP 7: Calculating the Final Cell Count

The cells/cubic mm is the number of cells counted times the dilution factor times the depth factor divided by the area counted.

cells counted = 500
depth factor = 10
dilution factor = 200
area counted = $\frac{1}{5}$

$$\frac{500 \times 200 \times 10}{\frac{1}{5}} = 5{,}000{,}000$$

Therefore the RBC is 5,000,000 cells/cubic millimeter.

RELATED PROBLEMS

For each of the following four problems

FIND: (a) dilution, (b) dilution factor, (c) depth factor, (d) area counted , (e) area factor, (f) volume factor, and (g) cells/cubic mm.

1) WBC pipette
   blood drawn to 0.5 ml mark
   5 white square counted
   456 cells found

2) RBC pipette
   blood drawn to 0.5 ml mark
   6 red squares counted
   1050 cells found

3) WBC pipette
   blood drawn to 0.8 ml mark
   4 white squares counted
   100 cells found

4) RBC pipette
   blood drawn to 0.2 ml mark
   chamber depth 0.2 mm
   10 red squares counted
   175 cells counted

5) Based on the final cell count of each of the above problems what might be the next step taken by the doctor in order to determine exactly what is wrong with the patient?

6) White blood cells are used to fight infections in the body. Why would a low white blood cell count indicate the presence of an infection in the body?

7) A MLT reported to his/her supervisor that the WBC for a certain patient was 160,000 cells/cubic mm. The supervisor asked the technician the level to which the blood was drawn and the number of cells counted. Blood was drawn to the 0.5 mark and 320 cells were counted. The supervisor then asked another technician to run a test. You are to assume the role of the second technician. What cell count did the second technician find? Does this agree with the first count? If the first count was inaccurate where did the first technician make his/her mistake? What consequences could have occurred due to the incorrect count being reported to the doctor?

PROBLEM 1 ANSWER KEY

a) Dilution Ratio: $\frac{.5}{10} = \frac{1}{20}$

b) Dilution Factor: The dilution factor is the reciprocal of the dilution ratio or:

$$\frac{1}{\frac{1}{20}} = 20$$

c) Depth Factor: Since no information was given concerning the counting chamber depth, assume a standard counting chamber depth of 0.1 mm. The depth factor is the reciprocal of the chamber depth.

$$\frac{1}{0.1} \text{ or } 10.$$

d) Area Counted: This is a WBC pipette, therefore the area counted is the same as the number of squares counted or 5.

e) Area Factor: The area factor is the reciprocal of the area counted or

$$\frac{1}{5}$$

f) Volume Factor: The volume factor is the area factor times the depth factor.

$$\frac{1}{5} \times 2 = \frac{2}{5}$$

g) Cells/cubic mm: The cells per cubic millimeter is the number of cells counted times the dilution factor times the depth factor divided by the area counted.

$$\frac{456 \times 20 \times 10}{5} = 18{,}240 \text{ cell/cubic mm}$$

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PROBLEM 2 ANSWER KEY

a) Dilution Ratio: $\frac{.5}{100} = \frac{1}{200}$

b) Dilution Factor: The dilution factor is the reciprocal of the dilution ratio or:

$$\frac{1}{\frac{1}{200}} = 200$$

c) Depth Factor: Since no information was given concerning the counting chamber depth, assume a standard counting chamber with a depth of 0.1 mm. The depth factor would be:

$$\frac{1}{0.1} \text{ or } 10.$$

d) Area Counted: Since this is a RBC count the area counted is the number of red squares counted (6) divided by the total number of red squares (25). Area counted equals

$$\frac{6}{25}$$

e) Area Factor: The area factor is the reciprocal of the area counted. This would be:

$$\frac{1}{\frac{6}{25}} \text{ or } \frac{25}{6}$$

f) Volume Factor: The volume factor is the area factor times the depth factor.

$$10 \times \frac{25}{6} = \frac{125}{3}$$

g) Cells/cubic mm: The cells per cubic millimeter is the number of cells counted times the dilution factor times the depth factor divided by the area counted.

$$\frac{1050 \times 200 \times 10}{\frac{6}{25}} = 8{,}750{,}000 \text{ cells/cubic mm}$$

PROBLEM 3 ANSWER KEY

a) Dilution Ratio: $\frac{.8}{10} = \frac{2}{25}$

b) Dilution Factor: The dilution factor is the reciprocal of the dilution ratio or:

$$\frac{1}{\frac{2}{25}} = \frac{25}{2} = 12.5$$

c) Depth Factor: Since no information was given concerning the counting chamber depth, assume a standard counting chamber with a depth of 0.1 mm. The depth factor is: 1/0.1 or 10

d) Area Counted: Since this is a WBC count, the area counted is the same as the number of squares counted or 4 squares.

e) Area Factor: The area factor is the reciporcal of the area counted or

$$\frac{1}{4}$$

f) Volume Factor: The volume factor is the area factor times depth factor.

$$\frac{1}{4} \times 10 \text{ or } 2.5$$

g) Cells/cubic mm: The cells per cubic millimeter is the number of cells counted times the dilution factor times the depth factor divided by the area counted.

$$\frac{100 \times 10 \times 12.5}{4} = 3{,}125 \text{ cells/cubic mm}$$

PROBLEM 4 ANSWER KEY

a) Dilution Ratio: $\frac{.2}{100} = \frac{1}{500}$

b) Dilution Factor: The dilution factor is the reciprocal of the dilution ratio or:

$$\frac{1}{\frac{1}{500}} \text{ or } 500.$$

c) Depth Factor: The depth of the counting chamber is 0.2 mm. The depth factor is the reciprocal of the depth of the counting chamber or:

$$\frac{1}{.2} = 5.$$

d) Area Counted: The area counted is the number of squares counted (10) divided by the total number of red squares (25). Area counted equals:

$$\frac{10}{25} = \frac{2}{5}$$

e) Area Factor: The area factor is the reciprocal of the area counted or:

$$\frac{1}{\frac{2}{5}} = \frac{5}{}$$

f) Volume Factor: The volume factor is the area factor times the depth factor.

$$\frac{5}{2} \times 5 = \frac{25}{2}$$

g) Cells/cubic mm: The cells per cubic millimeter is the number of cells counted times the dilution factor times the depth factor divided by the area counted.

$$\frac{175 \times 5 \times 500}{\frac{2}{5}} = 1,093,750 \text{ cells/cubic mm}$$

PROBLEM 5 ANSWER KEY

The answers will vary. However, the intent of this question is to get the students to think about possible steps the doctor might take after receiving the blood cell count. Possible answers may include requiring additional blood tests to narrow the number of possible illnesses, admitting the patient to the hospital for further tests, or prescribing some type of medication.

PROBLEM 6 ANSWER KEY

White blood cells fight infection. A low white blood cell count may indicate the presence of an infection that is being caused by a virus rather than a bacteria. The treatment for getting rid of a virus would not include the use of antibiotics. The virus that is present in the body is reducing the number of white cells in the blood that can be counted in a WBC.

PROBLEM 7 ANSWER KEY

The correct cell count is 16,000. The dilution is 1/20. The dilution factor is 20. The depth factor is 10. The area counted is 4 squares. The final cell count is

$$\frac{20 \times 10 \times 320}{4} = 16,000 \text{ cells/cubic mm}$$

The first technician used the wrong dilution ratio. A dilution ratio of 1/200 was used instead of 1/20. This gave an incorrect dilution factor of 200. Hopefully the students will pick up on the fact that 160,000 is 10 times 16,000. This will enable them to see rather quickly where the mistake was made.

Consequences of the incorrect count being reported could include the doctor prescribing a wrong medication, an improper diagnosis of the problem, the patient having to be put through additional, yet unnecessary, testing, etc.

GLOSSARY[6]

Anemia	A deficiency in the number of red blood cells in the body.
Antibody	Any of various proteins in the body that produce immunity against certain microorganisms and their poisons.
Antigen	A substance that stimulates antibody production.
Blood Banking	Drawing blood from a donor, separating blood into its components, identifying and matching of components to insure safe transfusion.
Chemistry	The analysis of the chemical composition of blood and body fluids.
Hematology	The laboratory area that counts, describes and identifies cells in blood and other body fluids. The information is used to detect anemias and leukemia among other diseases.
Immunology	The study of biological defenses against viruses or allergy-causing agents which most often cause antigen-antibody reactions.
Meningitis	Swelling of any or all parts of the brain and/or spinal cord caused by bacteria.
Microbiology	A branch of biology concerned with microorganisms such as bacteria and fungi.
Urinalysis	The chemical analysis of urine.

REFERENCES

American Society of Clinical Pathologists, Careers in Medical Laboratory Technology; Chicago: ASCP Board of Regents, 1989, pg. 3

Ibid., pg. 3

Ibid., pg. 3

Ibid., pg. 3

American Society of Clinical Pathologists, Preparing for a Career in the Medical Laboratory; Chicago: ASCP Board of Regents, 1989

Note: The definitions for blood banking, chemistry, hematology, immunology, and microbiology are from the publication Careers in Medical Laboratory Technology published by the American Society of Clinical Pathologists, Chicago, IL

FIGURE MLT-1

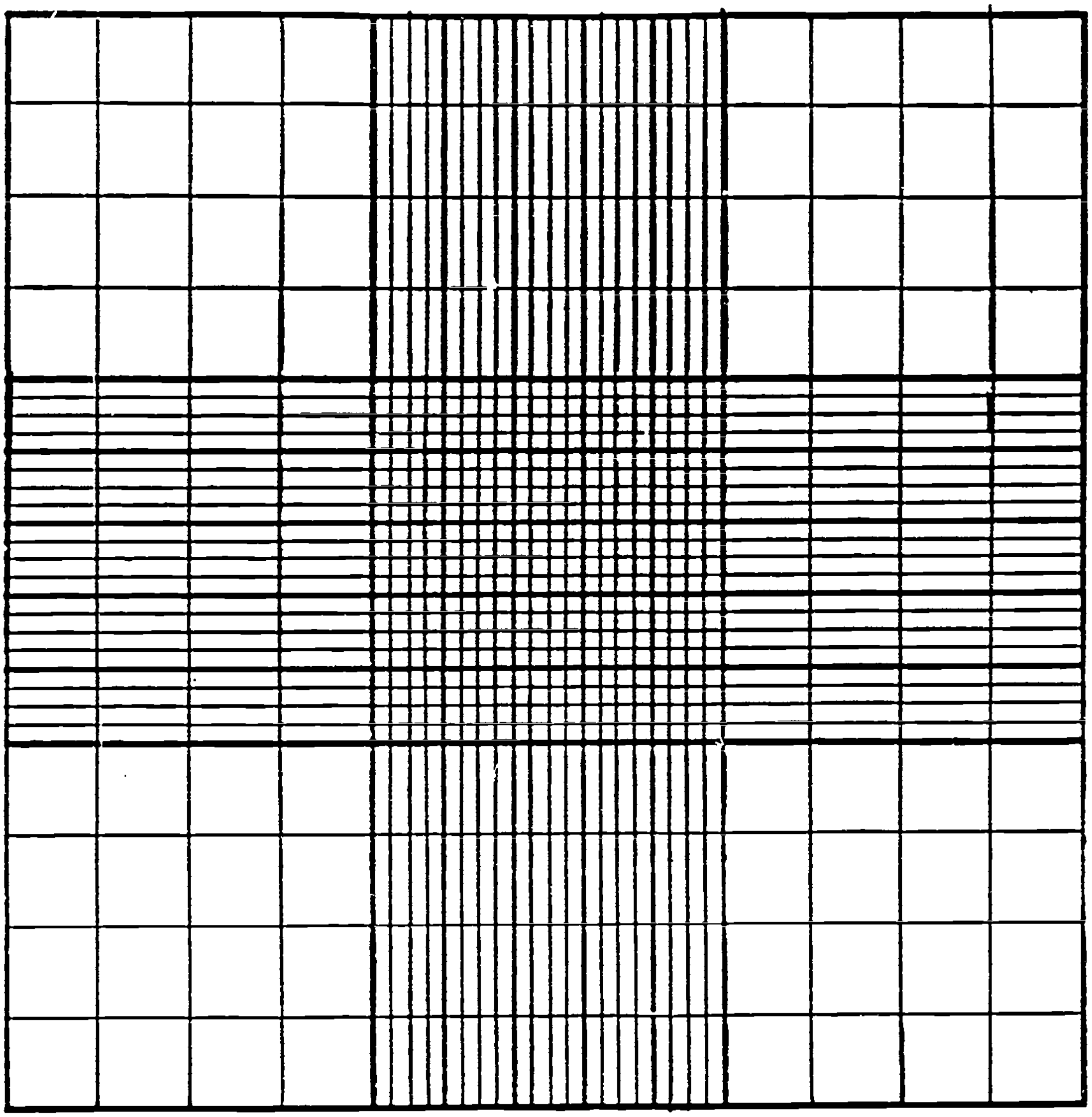

Figure MLT-1 illustrates the Improved Neubauer Hemocytometer, which is the most common type used to calculate WBC or RBC. This is an enlargement of the actual diagram the technician uses in counting the number of cells. The total area of the diagram is 9 square millimeters.

FIGURE MLT-2

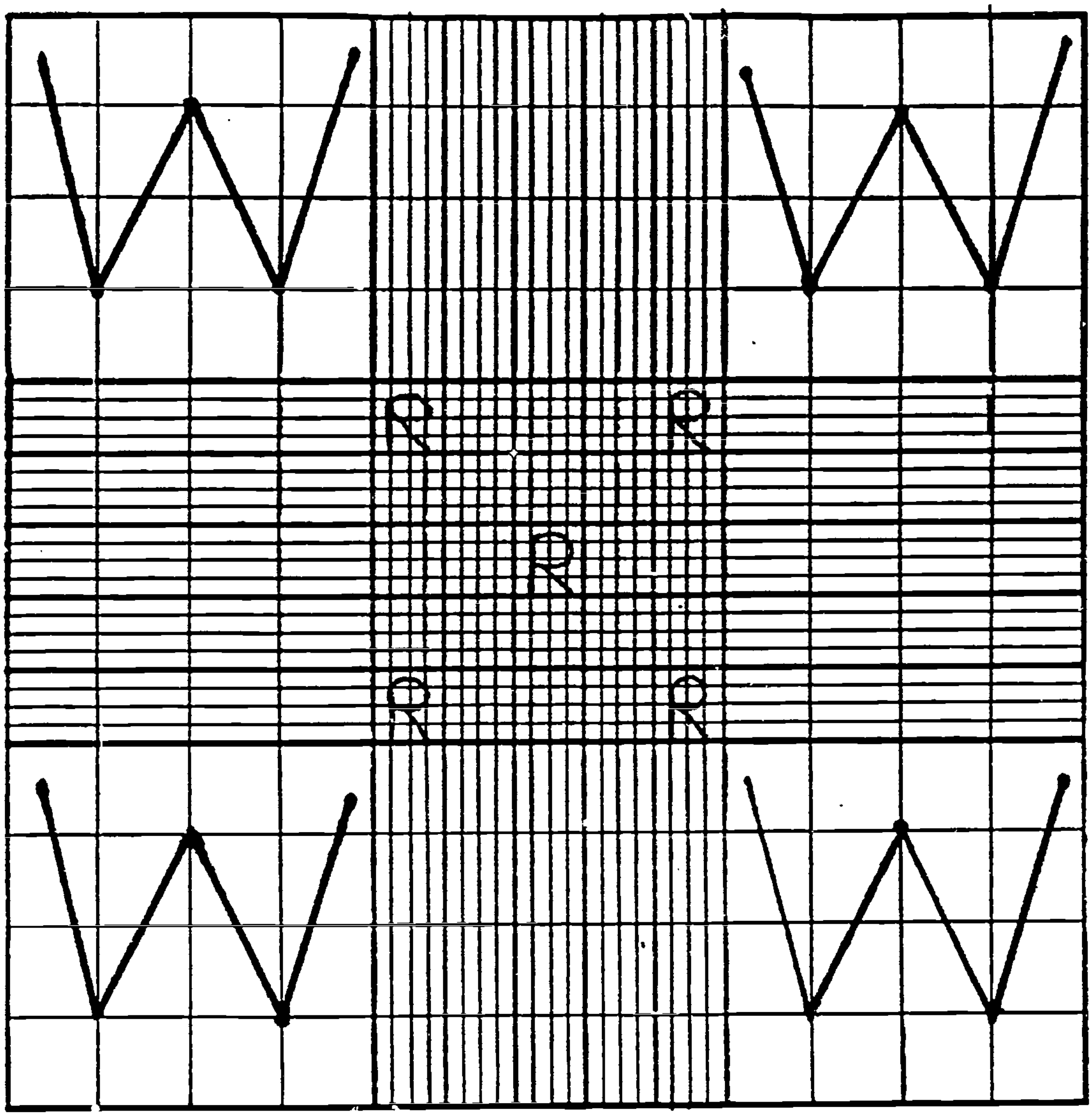

Figure MLT-2 shows which areas are used for the WBC or the RBC. The four large corner squares are referred to as white squares because they are used for the WBC. (Note: These squares are marked with a large "W". The "W" does not appear on the hemocytometer slide. It is only placed on this diagram for illustration.)

The central square is subdivided into 25 squares, often referred to as red squares, because they are used for the RBC. The four smaller, corner squares and the smaller, center square are used to performing the RBC. (Note: These squares are marked with a "R". The "R", like the "W" for the white squares, does not appear on the hemocytometer slide. They are only on this chart for illustration.)

WBC Counting Area

The areas counted in a WBC count are the four (one square millimeter) corners. These squares have the letter "W" in them. There are 16 squares in the one square millimeter. So the total number of squares counted would be 16 x 4 = 64. Each one square millimeter is counted by starting in the upper left hand corner.

START
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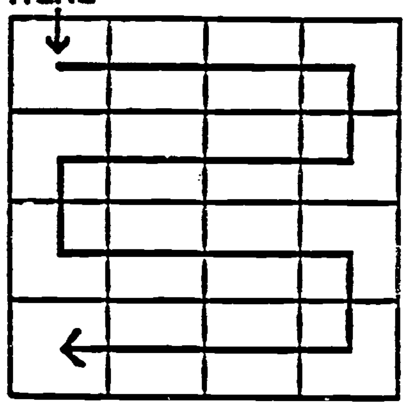
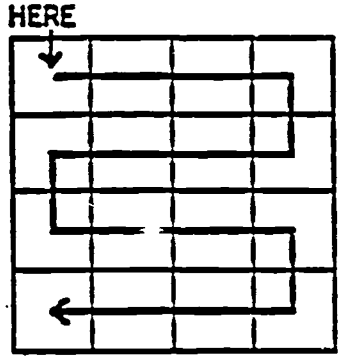


Start in the upper left hand corner. Follow path of arrow.

RBC Counting Area

The areas counted in a RBC count are located in the central one square millimeter. The four corners and the central small squares are counted. These squares have the letter "R" in them. There are 16 small squares in one of the "R" areas. So the total squares counted would be 16 x 5 = 90. Each square is counted by starting in the upper left hand corner.

START
HERE



Start in the upper left hand corner. Follow path of arrow.

FIGURE MLT-4

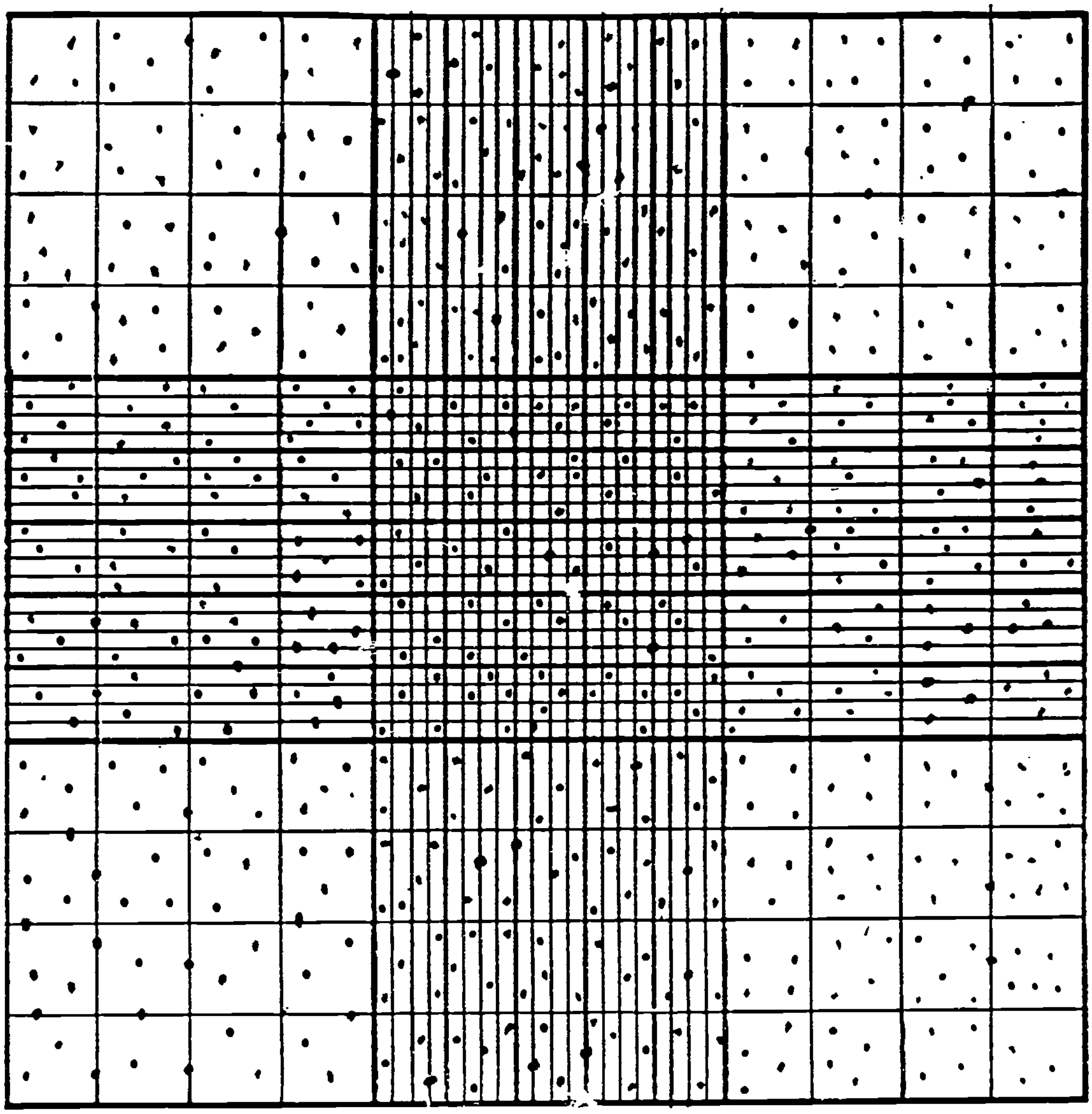


Figure MLT-4 is an illustration of what a technician would see when he looks at the specimen slide on the hemocytometer. The black dots illustrate the blood cells that are used in the counting process.